TDA Progress Report 42-70 May and June 1982

The DSN VLBI System Mark IV-86

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This article describes the DSN VLBI System Mark IV-86, Wide Channel Bandwidth (Block II). It covers the system requirements, description and implementation plans. Narrow Channel Bandwidth VLBI (Block I) was described in previous articles (Refs. 1,2).

I. Introduction

The DSN Very Long Baseline Interferometry (VLBI) System Mark IV-86 will be implemented to provide the radio source catalog and baselines maintenance for Galileo delta differential one-way range (delta DOR). The primary stations to be used for radio source catalog maintenance are the 34-m deep space listen-only stations that are planned for Goldstone, California, and Canberra, Australia. However, the 64-m deep space stations at each complex can also be used for Wide Channel Bandwidth (WCB) VLBI.

The Galileo precision requirement for radio source catalog is 25 nanoradians (15 cm), and 30 cm for baseline determination.

II. System Description

A. Definition

The Deep Space Communications Complex (DSCC) VLBI System is the assemblage of various subsystems at a specific complex which form an instrument for receiving and obtaining necessary VLBI data in conjunction with at least one other complex and, together with elements involved with the monitoring and control and data processing functions, comprise the DSN VLBI System.

B. Description

Functionally, the DSN VLBI System (Fig. 1) comprises the DSCCs, which individually receive the RF signal and downconvert segment bandwidths of the RF spectrum to videoband frequencies, which are then digitized and formatted by digital equipment. The digital data is then recorded on wideband recorders and shipped to the JPL/Caltech Correlator Facility for processing. Many of the functional blocks in Fig. 1 are common to both the Wide Channel Bandwidth (Block II) and the Narrow Channel Bandwidth (Block I) versions of the VLBI System. (See Refs. 1 and 2 for Block I description.)

The Antenna Subsystem is pointed to the appropriate signal source at the proper time by the Antenna Pointing Subsystem, which obtains pointing information (predicts) from the Network Data Processing Area (NDPA) of the Network Operations Control Center (NOCC) via the DSS Monitor and Control Subsystem (DNC) and the Ground Communications Facility (GCF).

The Antenna Microwave Subsystem (UWV) receives the signal flux gathered by the antenna. After amplification by the FET or TWM, the signal is sent to the Receiver-Exciter Subsystem, which heterodynes this signal to an intermediate frequency (IF).

The WCB system configuration will have 14 channels of 7 pairs (expandable to 28 of 14 pairs) of adjacent lower and upper sideband spectra selectable from 0.25- to 2.0-MHz bandwidths. These paired channels may be allocated as desired between S- and X-band frequencies, and each channel may be individually set to any place within the bandwidth, limited only by the front end amplifier and RF-IF downconverter. These frequencies are further downconverted from IF to video for the final acquisition and recording processes.

The Frequency and Timing Subsystem (FTS) provides the station local clock, using a very stable hydrogen maser as the primary standard. Reference frequencies and timing signals are derived from the clock for distribution to other subsystems. Similarly, a reference signal from the coherent reference generator (CRG), which distributes the reference signals, will drive phase calibration generators (PCG) as part of the Frequency and Timing Subsystem (FTS) via a coaxial-cable, phase-stabilization assembly which effectively translates the station's clock frequency stability to the comb generators in the PCG. The comb generator provides comblike, phase-stable, line spectra S- and X-band microwave frequencies, which are injected into the respective Microwave Subsystems prior to the input circuitry of the FETs or TWMs.

These phase-stable reference signals are amplified by the receiver and are down-converted simultaneously with the received signals. These reference signals will be used to calibrate out phase variations (which occur within the receiver, down converter, and digital subsystems) during the cross-correlation and data processing procedure. Since the comb signal encounters the received signal for the first time at the injection point, this point is established as the instrument's RF reference point for the DSCC VLBI System. This is the point at which the cross-correlation and postcorrelation estimation calculations refer the resultant Earth parameters, station location and clock offset and rate information relative to the other instruments.

The reference is used to relate other station references such as the station's location reference point (intersection of antenna axes or equivalent) and the Epoch reference point at the FTS CRG output located within the control room. The cable stabilizer effectively translates these points with a known time delay for interstation clock synchronization purposes. The clock Epoch reference point in turn will function as the reference for all subsystems and assemblies within the respective stations.

The data acquisition and recording subassembly records the data at rates up to 112 Mbits/sec. The tapes generated are shipped to the JPL/Caltech correlation facility for processing.

The sample of data from each radio source is transmitted via GCF wideband data line to the NOCC VLBI Processor Subsystem (VPS) for validation of fringes from the baseline pair of stations. The results are displayed to the Network Operations Control Team, and also transmitted to the stations for display.

The Deep Space Communications Complex (DSCC) Monitor and Control Subsystem (DMC) sends control and configuration information to the DSCC VLBI Subsystem (DVS) from data received from NOCC via the GCF. It also collects various calibration and configuration data which is provided to the DVS for recording with the VLBI data and via the GCF for monitoring.

At NOCC (Fig. 1), the NDPA uses data for real-time monitoring-display functions in the Network Operations Control Area (NOCA). The NOCA provides the control information to the DSCC, via the GCF, to the DMC.

The JPL/Caltech VLBI Processor receives tapes and performs the cross-correlation of the data from the observing stations and, with further postcorrelation and estimation processing, radio source catalog data and baseline data are generated.

III. Implementation

A. General

Implementation of Wide Channel Bandwidth (WCB) VLBI will provide a capability to maintain the radio source catalog and baseline distances. The WCB VLBI supplements the Narrow Channel Bandwidth (NCB) VLBI. The NCB VLBI is used for direct navigation support in determining relative clock and clock rate offsets, Universal Time 1 (UT1), polar motion (PM) and delta differenced one-way range (delta DOR).

A simplified block diagram of WCB VLBI is shown in Fig. 1. The WCB VLBI will be implemented on a 34-m listen-only antenna subnet. Effective bandwidth will be 400 MHz at X-band and 100 MHz at S-band. Sampling rates and recording will be at 14 Mbits/sec to 112 Mbits/sec. Tapes will be shipped to the JPL/Caltech correlator for processing.

B. Functional Performance Requirements

Parameter	X-band	S-band
System temperature	60 K	50 K
Bandwidth	400 MHz	100 MHz
Frequency range	8200-8600 MHz	2200-2300 MHz

Parameter	X-band	S-band
No. of channels	14 (expandable to 28)	
Channel bandwidth	2 MHz	
No. of tones/channel	3 (minimum)	
No. of sampling rate	14-112 Mbits/sec	

C. Modifications for WCB VLBI

Modifications to a standard 34-m listen-only Front-End Area (FEA) and Signal Processing Center (SPC) to provide WCB VLBI are given below.

1. **Microwave.** Wideband field effect transistors (FET) at both S- and X-band frequencies will be added with a bandwidth of 100 and 400 MHz, respectively. System temperature will be less than 50 K at S-band and 60 K at X-band. The frequency range will be at least 100 MHz at S-band from 2200-2300 MHz and 400 MHz at X-band from 8200-8600 MHz.

An insertion port for both S-band and X-band will be supplied as far forward in the microwave as possible in order to insert calibration tones for VLBI system calibration.

2. **Receiver.** An RF-to-IF conversion assembly will be added for both S- and X-band. The S-band will have a bandwidth ⩾ 100 MHz and range of 2200-2300 MHz. The X-band will have a bandwidth ⩾400 MHz and a range of 8200-8600 MHz.

3. **Phase calibration generators (PCG).** A PCG assembly will be added that will transfer the stability of the hydrogen maser frequency standard to the antenna microwave (UWV). At the UWV a coherent comb generator subassembly generates a comb of frequencies across the frequency range. This comb frequency divisor is selected so that at least three tones are in one 2-MHz VLBI channel.

4. **WCB VLBI Data Acquisition Assembly.** The Data Acquisition Assembly is located in the SPC and provides the following functions:

(1) Selects the IF signal.

(2) Selects frequency synthesis channels.

(3) Provides IF-video conversion.

(4) Provides image rejection and low pass filtering.

(5) Provides data sampling, formatting and recording.

(6) Provides selective data transmission via WBDL for validation.

Initially the Data Acquisition Assembly will provide 14 channels of 7 pairs of adjacent upper and lower sideband spectra, selectable from 0.25 to 2.0 MHz. The number of channels will be expandable to 28 channels of 14 pairs.

Data sampling and recording will be at 14 to 112 Mbits/sec. The format for recording will be compatible with the Mark III Haystack Observatory. Data transfer will be magnetic tapes shipped to the JPL/CIT correlator facility.

5. **Water Vapor Radiometer (WVR).** The WVR measures water vapor content along the line of sight in order to calibrate the VLBI data for this error source. The Advanced-Systems WVR models will be upgraded and integrated into the DSCC technical facilities. Data will be relayed from the technical facilities subsystem to the DSCC VLBI subsystem for incorporation into the VLBI data stream. These data will be used by the Block II correlator to calibrate VLBI observables for water vapor content along the line of sight.

The WVR measures the brightness temperature at two frequencies – 20.7 and 31.4 GHz. These brightness temperatures are used to determine the water vapor content along the line of sight. The WVR is slued with the main antenna; and periodic calibration is done by dipping in elevation at each 90° in azimuth.

6. **Block II correlator.** The Block II VLBI correlator is a joint JPL/Caltech implementation with the correlator located at the Caltech campus.

The Block II correlator will be implemented for the correlation and postcorrelation for 3 stations simultaneously (expandable to 7 stations). Data correlation will be to the rate of data acquisition. Data input will be VLBI data tapes.

In order to calibrate the VLBI data, known tone signals of constant frequency are injected in the microwave subsystem during a VLBI observation. During correlation, the correlator assembly will generate (with a local model) this same frequency and (by comparison to the injected constant frequency) measure phase change due to phase instabilities in the microwave and receiver subsystems.

Given a set of parameters, the software model calibrates the phase to within 10^{-5} cycle of fringe. Also, a record of the calculations along with their results are kept with a precision of 10^{-5} cycle of fringe. Output is available in both delay and frequency domain.

The software model constantly updates its computation of the required geometric time delay lag due to the Earth's rotation. Eight instantaneous lags (four preceding and four following the nominal geometric delay) will be provided to determine the actual geometric delay. The maximum equivalent error of the VLBI Block II processor tracking the model delay (the error in keeping constant the point of maximum correlation) will be 0.01 lag.

The JPL/Caltech VPS will be able also to process data collected and recorded by Goddard Space Flight Center (GSFC)/ Haystack Observatory Mark III VLBI System.

Postcorrelation functional requirements are as follows:

(1) Compute natural radio source and tone phase.

(2) Calibrate natural radio source phase for station instrument error.

(3) Compute calibrated natural radio source delay.

(4) Resolve cycle ambiguities.

(5) Calibrate for transmission media effects.

(6) Solve for natural radio source locations and baseline.

(7) Update radio source catalog and baselines.

References

1. Chaney, W. D., and Ham, N. C., "DSN VLBI System MK 1-80," *TDA Progress Report 42 56*, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1980.

2. Chaney, W. D., "The DSN VLBI System Mark IV-85," *TDA Progress Report 42-64*, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1981.

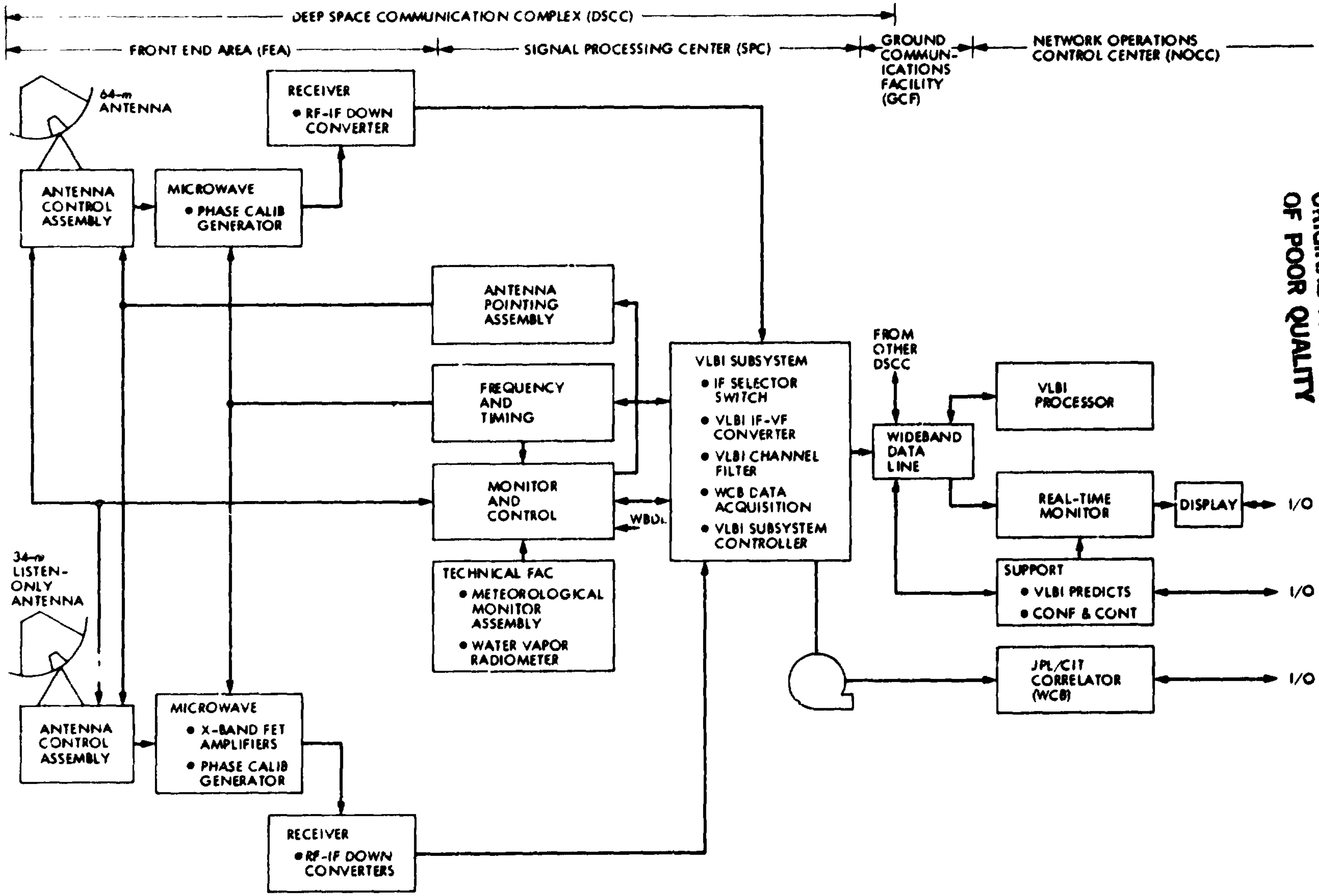

Fig. 1. The DSN VLBI System Mark IV-85 (simplified diagram)